Wax 22187

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18 February 1974

Packet Radio Temporary Note # 96

NIC # 22187

POWER SOURCES FOR REPEATERS AND TERMINALS

Abstract: Portable power for a repeater or terminal cannot be provided in small lightweight packages. It is recommended that (1) the equipment be designed to operate from 24VDC, (2) that the power source be outboard from the equipment and (3) the power source selected from a range of options depending upon deployment (AC-DC; silver-zinc/zinc-air/nickel-cadmium batteries; thermoelectric-battery hybrid).

INTRODUCTION

The terminals and repeaters are intended to be mobile equipment and as much as possible self-contained including the primary power source. This note reviews many of the available power source options.

The terminal requires the most mobility; thus, size and weight are the primary considerations. The operational useage can be described in terms of hours with a requirement to replace or recharge the primary power source frequently. The repeater must operate for weeks of unattended and somewhat unpredictable useage. Although the repeater must still be mobile, the size and weight can be sacrificed for life expectancy, reliability and minimum maintenance. The cost aspect impacts on the selection of the source and its capability to be discarded or rejuvenated.

RECEIVED AT NIC MARCH 19, 1974

Radio Equipment Loading

It is not the intent of this paper to describe in detail the voltages and current drain of the terminal and repeater. This will be derived separately. Estimates range between 15 and 60 watts. The major power surge is required for the 10W RF amplifier which, if left on, would consume approximately 42 watts from a 24VDC source. The PA is not very sensitive to supply voltage with the major effect being a drop in output power. Figure 1 shows some typical data of PA output power change as a function of supply voltage variation. Since regulation the high surge currents are on the 24VDC source, it would be desireable to have a primary power system that is 24VDC. If the voltage were lower, DC to DC converters would be required. This introduces more losses and requires the primary power source to be larger. The issues of power distribution in the equipment, dc to dc converters and efficiencies will be described in a separate paper when the equipment power requirements are defined.

The reason for mentioning the power at this time is to bias our thoughts towards a battery that has a flat voltage discharge characteristic and a voltage of 24VDC.

Summary of Power Sources Not Considered

Motor Generators: If a conventional gasoline engine is employed, the size, weight and heat generated are undesireable for the terminal configuration. For the repeater, the reliability of a device with many moving parts is low and the maintenance requirement high. Because of the energy crisis, there is interest in wind power generators. This is not considered a reliable solution at this time. A wind powered device would only be applicable as a charging system for batteries. There may be potential for specific repeater locations.

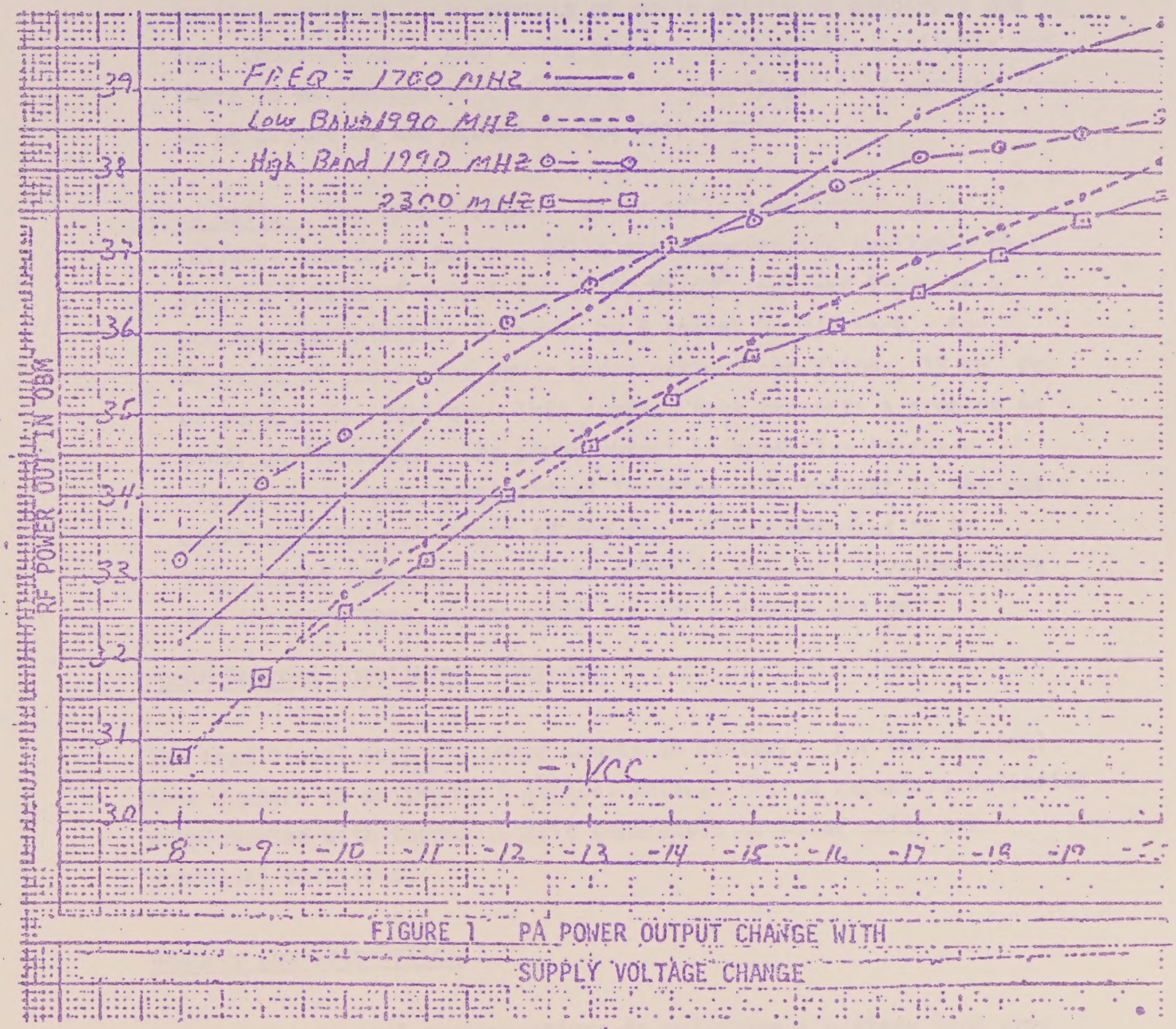
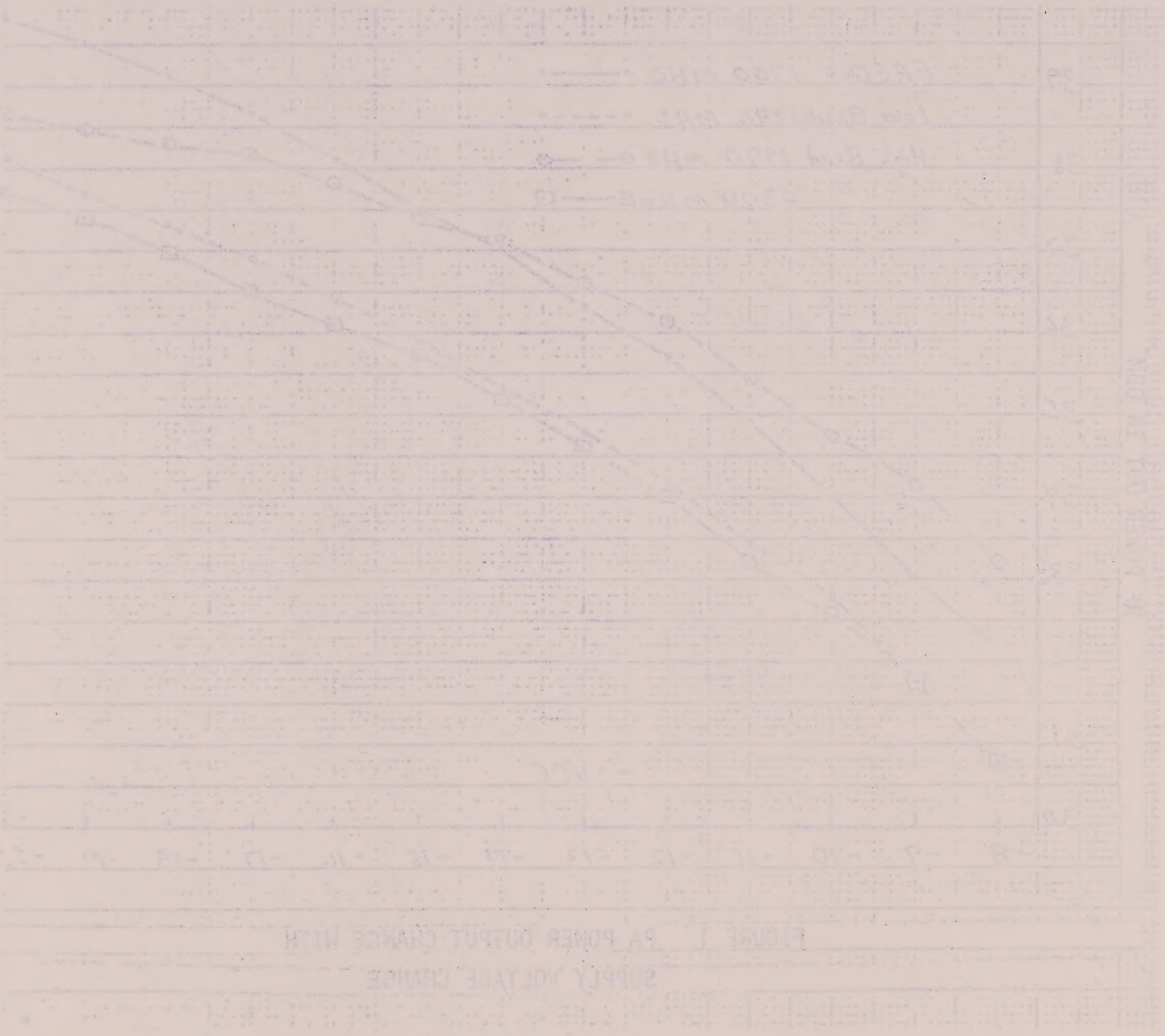


FIGURE 1 PA POWER OUTPUT CHANGE WITH SUPPLY VOLTAGE CHANGE



Fuel Cells: A review of several manufacturers indicates that the market is primarily oriented toward converting water to gas by using electricity rather than the reverse process. In general, the fuel cell systems have either turned out to be too complicated, too costly requiring large amounts of noble metals or dangerous due to fuel combinations. Fuel cells are not commercially available and there is no indication that there are advantages that warrant them to be placed on the market in the near future.

Solar Cells: For space flights, solar cells have proven to be a reliable source of power. Cells are commercially available that produce 1 watt of output for a 100 MW/CM^2 incident light in a package approximately 6 inches by 6 inches by 3/4 inch. For 50 watts of continuous power under optimum conditions, 13 sq. ft. of surface is required. This surface area presents a problem in windy environments. The power output is sensitive to shade, cloudy conditions, geographical location with respect to the sun's angle and seasonal length of the day. There promises to be significant research into solar cells in the next five years but for the near term, solar cells are not a viable option.

Power Sources Considered (General)

The traditional portable power source is battery. For the terminal, this appears to be the most logical choice. For a repeater, batteries supplemented with thermoelectric generators or solar cells are potential solutions.

Battery Characteristics

Some of the typical considerations in selecting a battery type are:

Nominal voltage
Current drain (average and surge)
Operating cycle
Life expectancy
Recharging
Service temperatures
Size and weight

Only secondary cells (cells that can be recharged) are considered. Table 1 is a summary of several of some secondary cell parameters. The silver zinc cell has high energy density both in weight and size. Eagle Pitcher Industries builds a silver zinc 800AH, 24VDC (approx. 19KW Hr) battery for satellites. The battery dimensions are 11.3 in. by 13.5 in. by 9.0 in., weighs 170 pounds (costs approximately $17,000). The zinc-air battery is also a unique battery with high energy density. Recharging the cell consists of replacing the zinc plates. If the equipment need not be left on, the battery can be deactivated. This has potential for the terminal equipment. The self discharge characteristic of the cells is of primary concern for a repeater. Even if there is no load, the cell will drain itself. As seen from Table 1, only silver-zinc, silver cadmium or lead acid will hold a charge for six months or longer. The life expectancy is a measure of when the cell must be salvaged and rebuilt or disposed of. Variations of cell capacity with temperature is also a factor. Figure 2 shows the variation of some of the cells as a function of temperature. The figure shows the lead acid cell to suffer from loss of capacity at lower temperatures. If the lead acid cell is left in a discharged condition, it could suphate, requiring that the battery be salvaged. Another factor in selecting batteries or cells is the voltage variation as the cell discharges. Nickel cadmium and zinc air have very flat voltage characteristics. Figure 3 is a typical discharge characteristic of the batteries considered. The zinc air has a flat voltage during discharge which allows this type of battery to power circuitry directly without regulators. The lead acid battery voltage changes considerably during discharge and could not be a long term power source without a regulating device.

As a reference for anticipating battery size and weight for average power drain and the length of operation required, Figures 4 and 5 are presented. Figure 4 is aimed primarily at a hand held or suitcase terminal where Figure 5 is for long term operation as for a repeater. In both cases, the battery weight is described in terms of the maximum and minimum energy density devices. The size is also described in two scales representing the range of values depending upon selection of a battery. Note should be made of the battery weight in terms of tons. This corresponds to a lead acid battery system.

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TABLE 1: SECONDARY BATTERY CELLS

TYPE	ABBR	OPEN CKT V	WORKING VOLTAGE	ENERGY DENSITY		RECHARGE CYCLES	SELF DISCHG. @ 70°C	LIFE EXPECTANCY
				WHR/lb	WHR/Cu.In.			
Silver Zinc	Ag/Zn	1.6-1.8	1.3-1.6	25-95	1.3-6.8	500	1 yr	1 yr. wet/2-5 yrs. dry
Silver Cadmium	Ag/Cd	1.4	0.8-1.1	11-33	0.6-2.8	200-3K	6 mo.	1 to 5 yrs. wet/5 yrs.
Nickel Cadmium	Ni/Cd	1.3	1.0-1.2	8-17	0.5-1.9	> 1K	3 mo.	> 5 yrs.
Zinc Air	Zn	1.4-1.5	1.2-1.3	25-100	3.0-8.0	50	36 hr.	36 hr.active/5 yr. she
Lead Acid	Pb	2.12	1.5-2.0	10-15	0.7-1.4	> 1K	1 yr.	3-5 yrs. wet/5 yrs. dr
Nickel Zinc	Ni/Zn	1.8	1.5-1.6	20	1.4	150	1 mo.	> 1 yr.

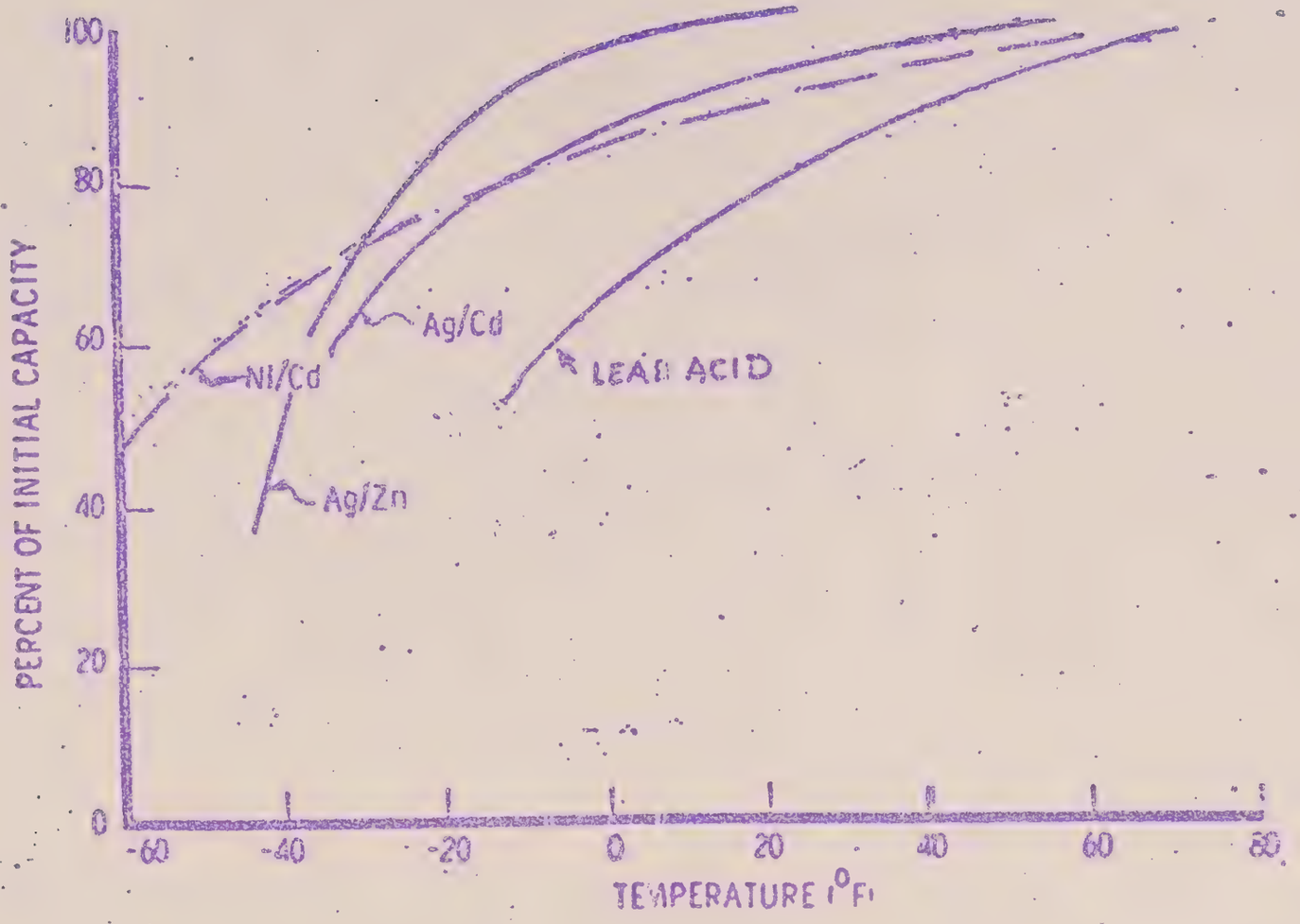
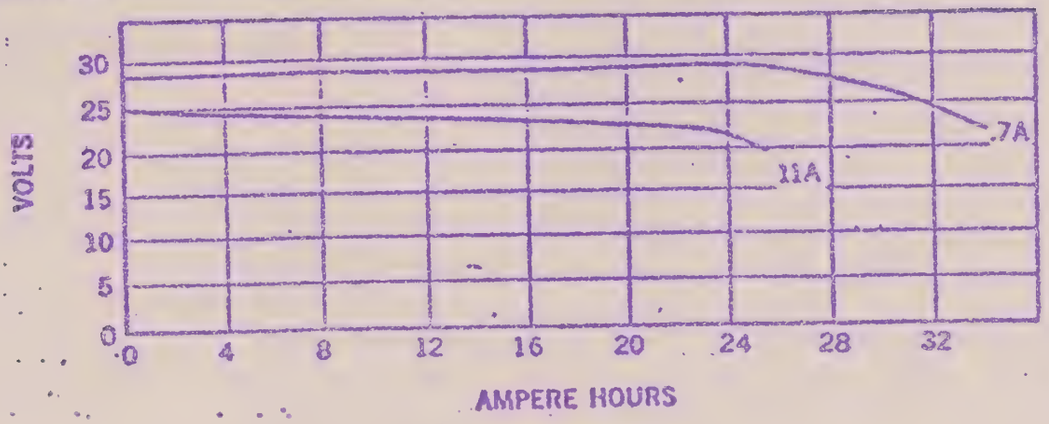


FIGURE 2 : CAPACITY RETENTION OF ELECTRO CHEMICAL CELLS DURING LOW DISCHARGE RATES AS A FUNCTION OF TEMPERATURE.

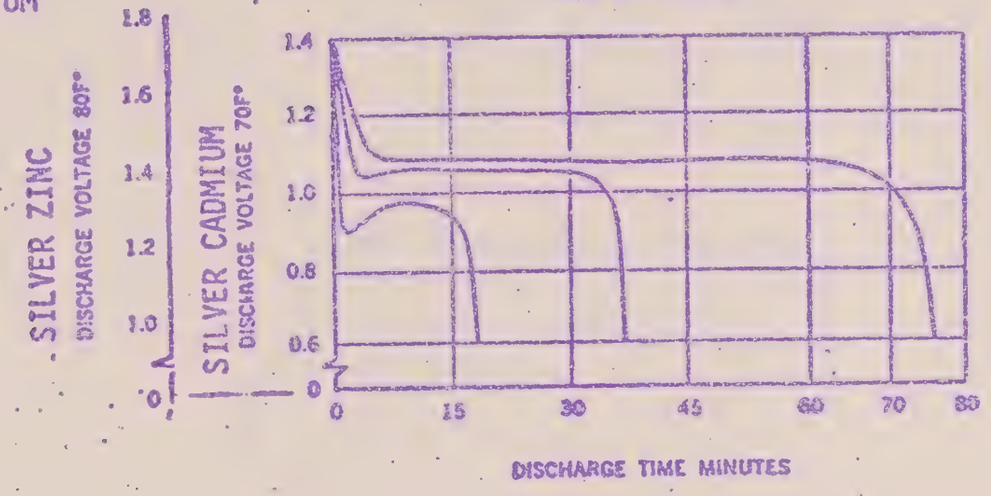
ZINC AIR BATTERY

DISCHARGE CHARACTERISTICS AT +70F°



SILVER ZINC
SILVER CADMIUM

TYPICAL CAPACITY AND VOLTAGE CHARACTERISTICS
HIGH RATE CELLS



NICKEL CADIUM

TYPICAL CELL DISCHARGE CHARACTERISTICS
(80F° DISCHARGE)

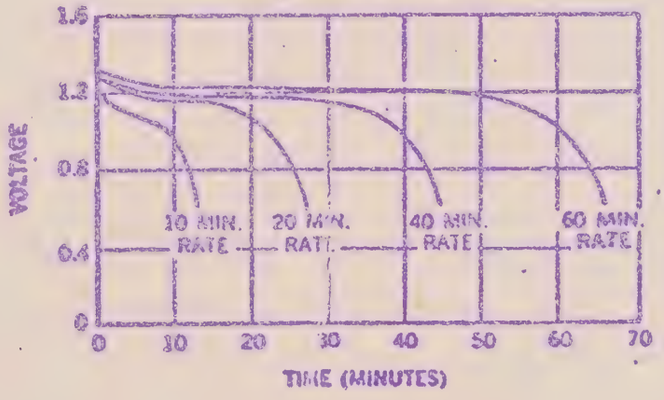
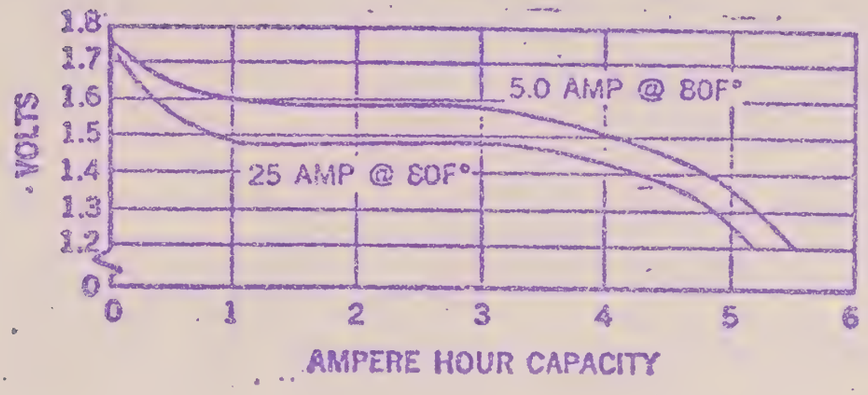


FIGURE 3: BATTERY DISCHARGE CHARACTERISTICS

NICKEL ZINC

TYPICAL DISCHARGE CHARACTERISTICS

NZS-5.0



LEAD ACID

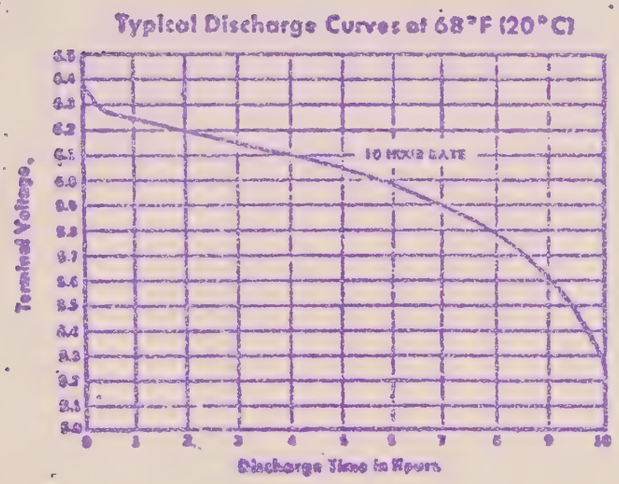


FIGURE 3 (CONTD): BATTERY DISCHARGE CHARACTERISTICS

FIGURE 4.

BATTERY CAPACITY - WEIGHT - SIZE

VS. DURATION OF OPERATION

(SHORT TERM)

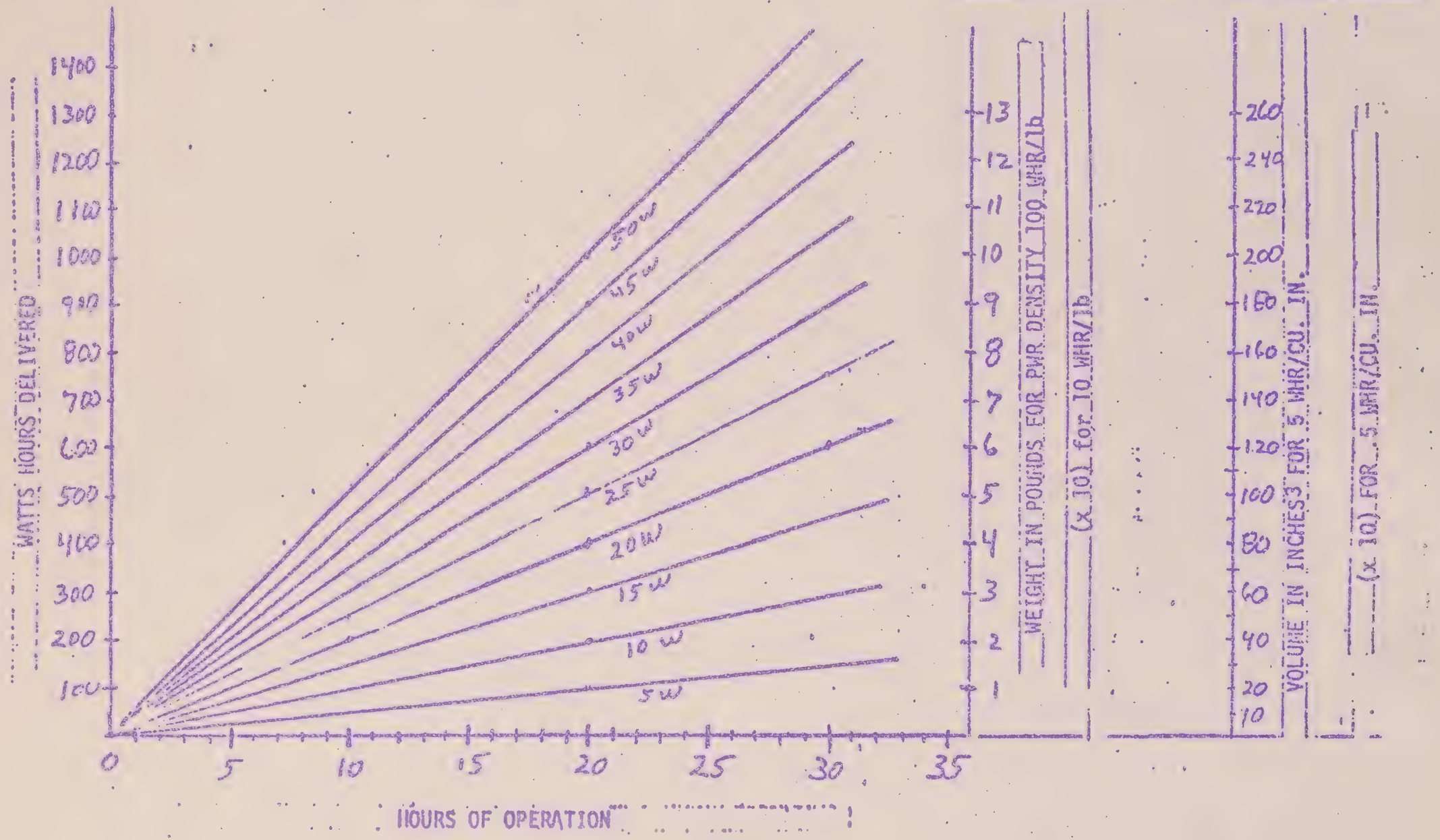
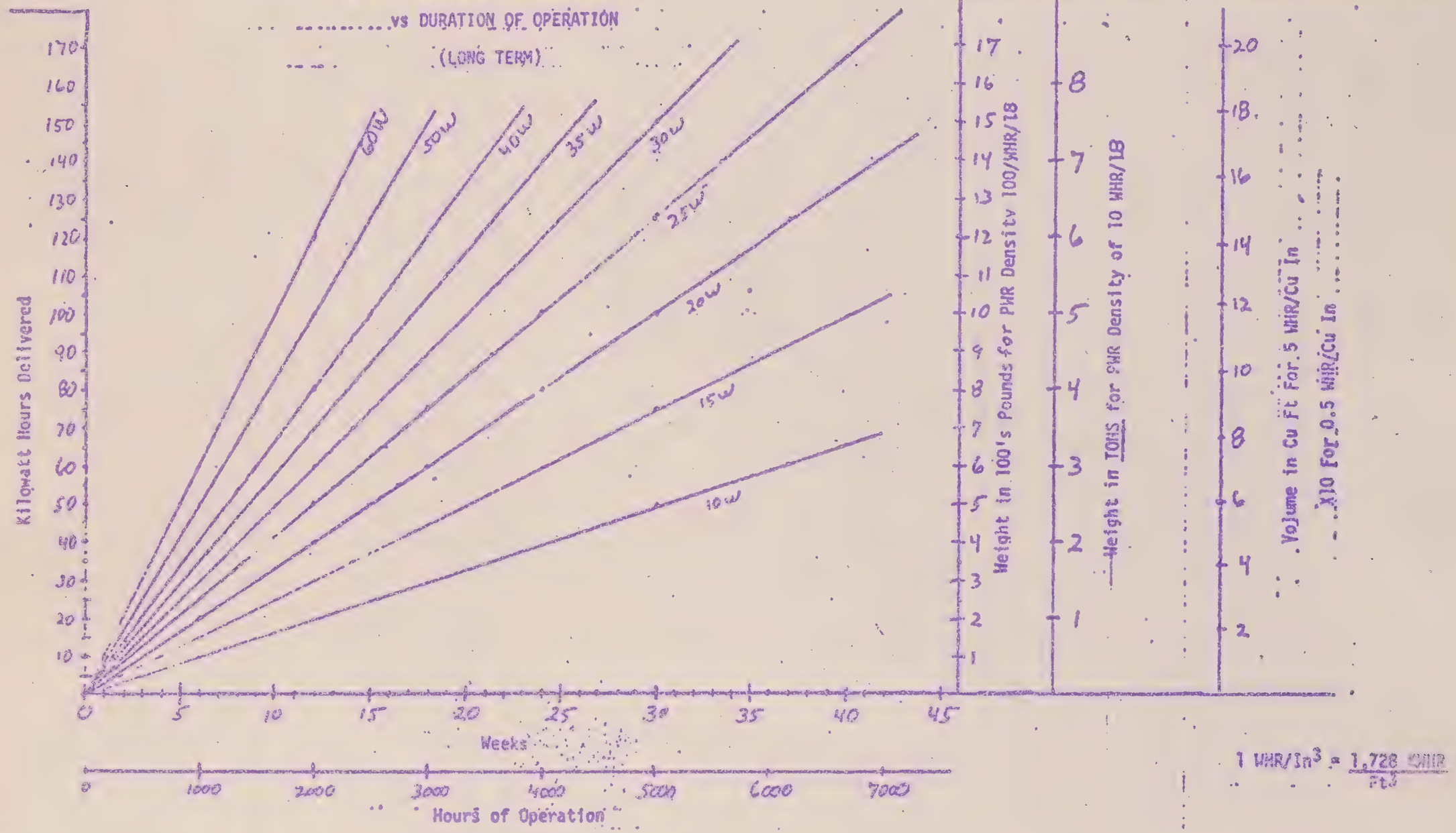


FIGURE 5

BATTERY CAPACITY - WEIGHT - SIZE

vs DURATION OF OPERATION

(LONG TERM)



1 WHR/In^3 = $\frac{1,728 \text{ WHR}}{\text{Ft}^3}$

Thermoelectric Generators

Thermoelectric generators are heat engines which convert heat energy to electrical energy. The electrical energy is obtained directly by causing a temperature difference across a thermopile consisting of pairs of positive and negative thermocouples. The thermocouple utilizes the Sebeck effect. The larger the difference between hot and cold junctions of the thermocouple, the larger the generated voltage. No moving parts are required to obtain power. This type of generator is commercially available from several companies. The heat source can be nuclear, gas (propane, butane, or natural gas) or liquid fuels. Because of the simplicity of the device, the life expectancy is long (greater than 10 years), maintenance is minimum, usually only being an annual cleaning of an air filter and gas jet, and reliability is thus high. The main considerations are:

Power requirement
Size and weight (generator and fuel)
Fuel consumption
Type of heat source
Environmental considerations
Failure modes

Several nuclear powered generators have been built for under-water, polar wastelands or spacecraft applications. Their reliability has been proven by systems operating in excess of five years. The cost and testing required by the Automic Energy Commission make this option only applicable for those situations where extremely long life and reliability are required.

Three gas powered thermoelectric manufacturers are compared on Table 2. Propane was selected as the fuel for all units because of its boiling point of -43°F. Butane, on the other hand, boils at +31°F, which is not low enough if the system is to be deployed in cold climates. All the generators were selected from manufacturers' brochures for 50 to 60 watts of power at 24VDC. The Teledyne unit has a flame-

TABLE 2: THERMOELECTRIC GENERATORS

OUTPUT VOLTAGE +24VDC

MFGR	MODEL	COST ($)	OUTPUT POWER (WATTS)	PROPANE LBS/WK	UNIT WEIGHT (POUNDS)	DIMENSIONS (INCHES)	BLOWER
THERMO ENERGY CONVERTER CORP.	2A80L-24	2K	53	39.8	76	24 x 24 x 13 1/4	Yes
3M	520H-24	3K	50	45.4	90	37.5 x 20 x 17	No
TELEDYNE	2T6	-	60	67.2	130	30 x 25 x 17	No

less heating chamber. It thus avoids being extinguished by high winds as do the other two manufacturers that have a flame. A re-ignition capability is provided for the flame type units to overcome this failure mode. The flame is contained within several layers of housings so that rather high winds, in excess of 70 mph, are required to affect the chamber. The units require oxygen for burning and are affected by altitude. Operation from below sea level to 13,000 feet can be obtained with standard units. Figure 6 shows some of the performance parameters of the 3M Company device. As would be expected, the power output is a function of ambient temperature. The power and voltage characteristics as a function of load resistance show that the source impedance is relatively high, greater than 1 ohm. Efficient use of a thermoelectric generator requires that the load be matched to the device. For this reason, a hybrid system using batteries to absorb surges is normally used. The low impedance voltage regulation provided by a battery complements the thermoelectric generator.

The major factor not addressed is the storage space and weight required for fuel as a function of the time duration for unattended operation.

Figure 7 shows the weight of propane fuel as a function of manufacturer and duration of operation required. Six months of operation would require 1050 pounds of propane @ 40 lbs/wk or 1800 pounds @ 70 lbs/wk. This does not include a container for the propane. As a general rule, the tank weight is approximately 75% of the fuel capacity weight. Thus, to store 1000 lbs of propane would require a tank weighing 750 lbs. As a specific example, a commercially available tank weighing 300 lbs will hold 420 lbs (99 gallons) of propane. Its size is 29" in diameter and 56 1/4" high. Three to four tanks would be required for 6 months of operation.

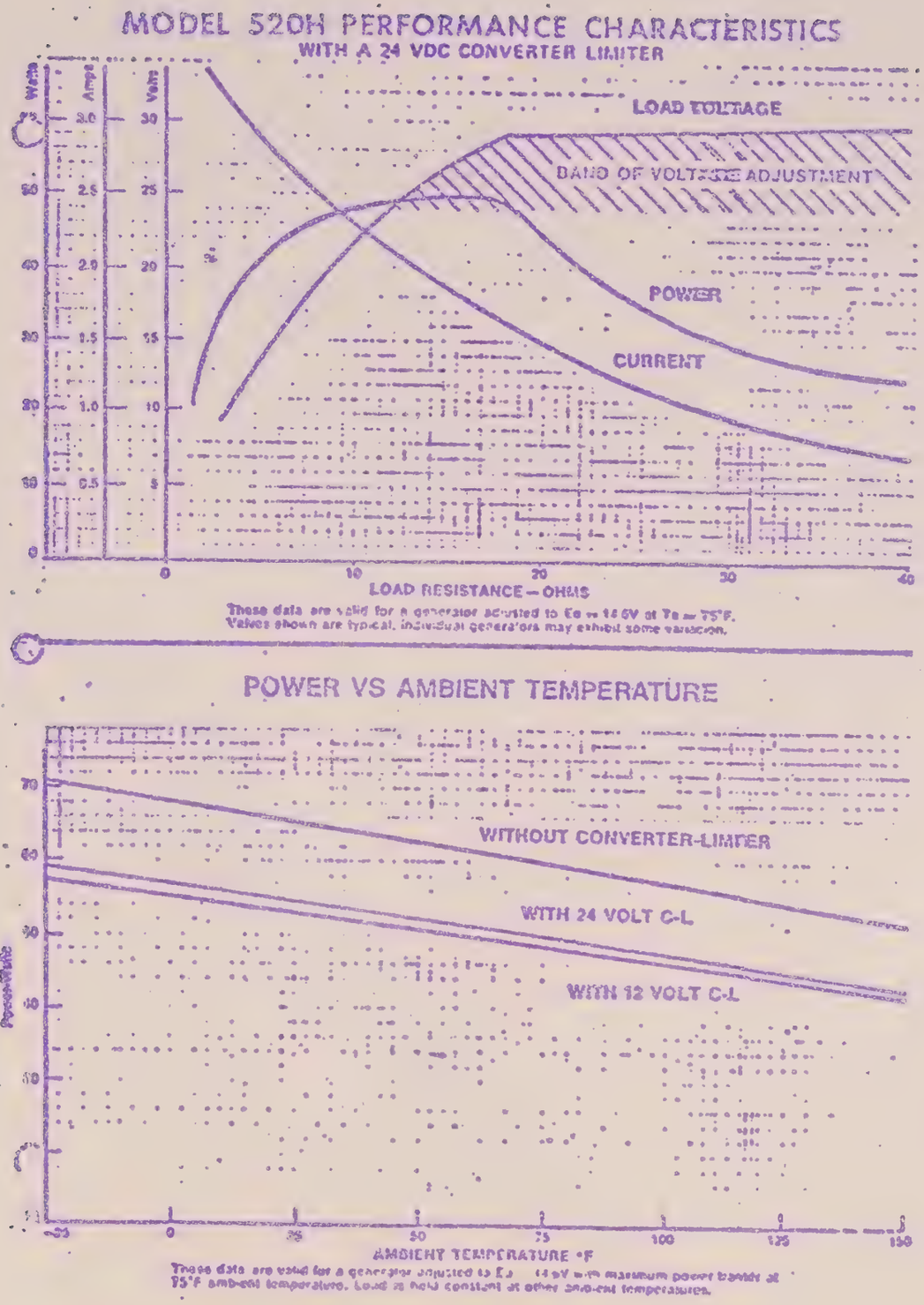

MODEL 520H PERFORMANCE CHARACTERISTICS
WITH A 24 VDC CONVERTER LIMITER
Watts
Amps
Volts
LOAD VOLTAGE
BAND OF VOLTAGE ADJUSTMENT
POWER
CURRENT
LOAD RESISTANCE — OHMS
These data are valid for a generator adjusted to Eo = 14.6V at Ta = 75°F.
Values shown are typical, individual generators may exhibit some variation.
POWER VS AMBIENT TEMPERATURE
WITHOUT CONVERTER-LIMITER
WITH 24 VOLT C-L
WITH 12 VOLT C-L
Percent Watts
AMBIENT TEMPERATURE °F
These data are valid for a generator adjusted to Eo = 14.6V with maximum power loaded at
75°F ambient temperature. Load is held constant at other ambient temperatures.

FIGURE 6: THERMOELECTRIC SOURCE CHARACTERISTICS

Recommended Approach

It appears obvious that a terminal or repeater cannot initially be constructed to be lightweight and compact if the power system is integrated into the unit. The equipment should be designed to operate from 24VDC which will allow the system to be powered in many ways. For general use, a conventional AC-DC power supply; for short term useage in an area where power is not available, a pair of 12VDC lead acid cells can be quickly and easily obtained. Where this is a continuing service with easy access but not a permanent installation, higher capacity Nickel Cadmium cells can be used and recharged. For permanent unattended installations, a nuclear or propane thermoelectric generator and nickel cadmium battery combination is recommended. (The nuclear system will be more mobile). A propane system must be considered a semi-fixed site and might be well to consider a shelter construction as a long term solution. For the terminal, an outboard battery pack of nickel cadmium or silver zinc is recommended. A zinc air system is an option where prolonged field use is required. A 24VDC, 25AH battery weighing 12 pounds can be deployed. When not in service, the plates can be removed, deactivating the cell. Recharging the system requires about 1 pound of zinc plates. Thus, carrying 15 pounds to the field would provide 100AH of service at 24VDC (2400 WHRS) or 2 days of continuous operation of a 50 watt device.

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